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AMERICAN METEOROLOGICAL JOURNAL.

A Monthly Review of Meteorology, Medical Climatology, and Geography.

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THE AMERICAN
METEOROLOGICAL JOURNAL.

VOL. IV. ANN ARBOR, SEPTEMBER, 1887. No. 5.

CURRENT NOTES.

THE first white frost is reported from Welisville, N. Y., on the night of August 6th.

HAIL INSURANCE.—It is reported that in Italy one hail insurance company whose income exceeded 2,000,000 lires, was just able to get through the year. Another company reports a loss of 487,658 lires upon last year's transactions.

SHOWER OF BLACK RAIN.—A very strange atmospherical phenomenon was witnessed at Castlecomen, Ireland, on April 30th. A general depression was felt all over the district in the afternoon, accompanied by lightning and thunder and a tremendous rain-fall, which continued till about 7 o'clock. At about 7:50 P. M. a thick black rain fell, sufficiently black to stain any white cloth, and apparently impregnated with an insoluble dust. The water of the local streams and cisterns was discolored, and in many places could not be used for domestic purposes.—*Symons's Met. Magazine.*

THE ROYAL PRUSSIAN METEOROLOGICAL INSTITUTE.—Dr. Hellman's recent history of this Institute brings out some facts of interest. Since the foundation of the Institute it has had 317 stations, reporting to it a total of 3,623 years of observation, or an average of 11.4 years for each station, 57 of these stations have continued their records for more than a quarter of a century, and 22 for over 35 years. Nearly half of the observers

were teachers of various grades, generally of the higher schools. Next to them come persons holding minor places under the government. As a matter of statistics it is found that observations taken in large cities are apt to be continued longer than in small places. In cities of over 100,000 inhabitants the average length of the series now held by the Institute is 24.3 years; for places of 5,000 to 10,000 it is 12.2 years, and for those with less than 100 inhabitants it is only 7.1 years. The growth in number of stations was pretty steady until 1871, when it decreased slightly for five years; since then the increase has been very rapid.

THE CITY OF MEXICO is in danger of being flooded. The rain-fall has been very heavy for a few days, and on the evening of July 28th many streets were under water. Lake Tezcoco, into which the city is supposed to drain itself, is almost filled with *debris*, and an inundation is imminent. Two centuries ago the city was inundated, causing damage to the amount of forty millions of dollars.

PHOTOGRAPHS OF LIGHTNING.—The following circular letter has been issued by the Royal Meteorological Society:

SIR.—The Council of the Royal Meteorological Society are desirous of obtaining Photographs of Flashes of Lightning, as they believe that a great deal of research on this subject can only be pursued by means of the Camera.

The Council would esteem it a great favor if you, or the Institution which you represent, could give them any assistance in this matter, either—

1. By sending them copies of any Photographs of Flashes of Lightning that may have been already taken;

2. By endeavoring to procure them yourself; or to interest others in the work.

It may perhaps be well to mention that the Photography of Lightning does not present any particular difficulties. If a rapid plate and an ordinary rapid doublet with full aperture be left uncovered at night during a thunder-storm for a short time, Flashes of Lightning will after development be found in some cases to have impressed themselves upon the plate. The only difficulty is the uncertainty whether any particular flash will happen to have been in the field of view.

The Council hope that now the Thunder-storm season is approaching, many Photographers may be found willing to take up this interesting branch of their art.

I am, Sir,
Your obedient Servant,
WILLIAM MARRIOTT,
Assistant Secretary.

OCCURRENCE OF FROSTS.—The voluntary observer at Manatee, Fla., lat. 27° 27′, long. 82° 35′, reports:

"Several farmers have informed me of queer streaks in which frost is appearing. In one field, where tomatoes were planted, every plant was killed, excepting two rows in about the middle of the field. Another farmer noticed in a field of beans that frost killed in spots, the whole field being apparently level. Several others give about the same experience."

Very slight undulations in the surface of the ground would permit the coldest air to settle in the lowest places. Variations in the conditions, quality, color, or constitution of the soil would permit some parts of the field to radiate heat and cool more rapidly than others; variations in the conditions of the plants, so that the sap of some are more easily frozen than others. A trough or general slight incline of the field may cause a flow of air along a few rows of vegetables and save them from freezing. Special parts of the field that are wetter than others will not suffer as much from frost as neighboring dry spots, because the upward conduction of heat prevents the cooling to the freezing point. When such peculiarities are noted by observers they will assist in reaching a solution if they will report in reference to both the frosted and unfrosted places: (1) as to the difference in elevation; (2) whether the soil is light or heavy; (3) whether the surface has been cultivated since rain has fallen; (4) does either portion appear to be more moist than the other; (5) did adjacent bushes or trees protect either portion from the wind, if any; (6) whether the unfrosted parts were near trees; (7) any other relative conditions noticed. [Editor *Review.*]

—*Monthly Weather Review.*

JULY WEATHER ON PUGET SOUND.—What a limited conception Chicago editors have of this country. Here is the Chicago *News* of July 6th, describing the temperature of the preceding day: "Every thermometer told the man on the street that it was 96° above zero in the shade. * * The hot wave extended throughout the entire country, the lowest temperature on record

being 80°. It was 90° at Alpena, Mich.; at Detroit, 96°; Chicago, between 95° and 100°; Cleveland, 99°; Pittsburgh, 99°; New York, 99°; Washington, 99.50°; Philadelphia, 98°; Baltimore, 100°; Wilmington, Del., 100°; Richmond, Va., 104°; St. Louis, 102°. In Louisiana and Mississippi, where rains were reported, the record was 90°. It was just as warm at Duluth and St. Paul, and in all the West and Northwest, and the temperature throughout the East averaged about the same."

It is not wonderful that the average Eastern newspaper readers should have indefinite and limited impressions in regard to the Pacific Coast, when the "great editors" of Chicago are so poorly equipped with current information about the weather and climate of the great Northwest, which is apparently beyond their range of vision. They appear to look upon the territory bounded by the Atlantic Ocean and the Mississippi and Missouri rivers as the entire country in regard to which they need to have the slightest concern, and they measure everything by the limited standards of this area. Why, according to the geographical experts, right here in Puyallup, we are yet east of the central meridian of United States territory, and would have to go several miles out upon the Pacific Ocean to reach the central point. But, coming back to the weather, let us compare our record of July 5th with that given by the Chicago *News* on the same day. The temperature recorded at Tacoma was as follows: Seven A. M., 60°; 2 P. M., 77°; 9 P. M., 66°; mean for the day, 68.3°; wind north; weather clear. But this was an exeeptionally warm day for the first half of the month, as the following table, compiled from the same record, will show:

TACOMA TEMPERATURE, JULY.

Date.	7 A. M.	2 P. M.	9 P. M.
1st	63	70	65
2d	64	73	68
3d	60	68	58
4th	57	70	61
5th	60	77	66
6th	64	77	68
7th	66	78	65
8th	57	75	67

9th	61	70	61
10th	51	67	62
11th	51	60	55
12th	54	69	59
13th	54	64	55
14th	55	65	54
15th	50	60	58
16th	56	72	64
Means	62	69	61.7

Daily mean temperature, 64.2°.

Think of this, ye perspiring wretches, sweltering in eastern zones, dying by scores from heat prostration, whose relief from an intense heated term comes in the death-laden lightning, the tornado and the cloud-burst! No wonder that your editors ignore the climatic facts of the Pacific Northwest, towards which the immigrating tide is steadily increasing, and endeavor to keep up the impression that the entire continent is afflicted similarly to the eastern section.—*Puyallup* (Wash. Ter.) *Commerce.*

New Meteorological Publications in Mexico.—The first memoir of the scientific society "Antonio Alzate" has been received. It is published under the auspices of the Meteorological Observatory in the City of Mexico. This society was founded in Oct., 1884, with Professor D. Alfonse Herrara as president. Its object is to promote the study of the sciences, to collect specimens on natural history, to collect geological and topographical data, and to make meteorological observations. The first memoir contains a paper by Rafael Aguilar "*Relating to the nature, production and use of ozone;* a mathematical paper on the *Variability of functions,* by Manuel Maroquin of Rinera; a chart giving a resume of the meteorological observations for the year 1883, and a paper giving the place of work of the society. *The Boletin de Estadistica* of the state of Puebla, has made its appearance. The first number, issued July 15, contains the meteorological observations for April from the station "Rosendo Marquez," District of Matamoras, J. M. H. Sanchez, observer. It also contains an exposition of the scheme of the new weekly *Bulletin of Statistics.* Number two contains a

meteorological summary for April from the District of Cholula, station "Porfirio Diaz," Federio Hernandez, observer, and for the same month from the District of Acatlan.

THE RAIN-FALL IN AUSTRALIA.—So much is said about the drought of Australia that very few persons are aware that the average rain-fall in all the colonies will compare favorably with that of other countries. In New South Wales, a territory of 310,000 square miles, the average rain-fall is twenty-four inches. At Sydney it is about fifty inches, at Eden it is seventy inches, but in the flat country it is only about ten inches. The average rain-fall in Queensland is about the same as that of New South Wales. The former colony, however, is more subject to tropical rains than the latter. The rain-fall, therefore, in Queensland rises in some districts, as for instance Johnstone River, to 123 inches; in other places the average is a low as eight inches.

At Adelaide, South Australia, where there are no high coast ranges to arrest the drift of the clouds, the rain-fall is as low as twenty inches. At Port Augusta it falls to eight inches. At Perth, Western Australia, the average is thirty-one inches, but at Canaroon, in the same colony, it does not average more than six inches. At Eucla it is ten inches. The rain-fall in Victoria varies from sixty-three inches at Cape Schanck to twelve inches at Wycheprof. At Melbourne it is about twenty-five inches.

The trouble, however, in Australia, is that whenever there is a diminished rain-fall the effects are much more disastrous than in other places, on account of the great heat of the sun and the absence of more general cultivation. A diminished rain-fall of 50 per cent. has at times desolated vast tracts of country. The report of the New South Wales royal commission, however, states that while one part of the country suffers from a diminished rain-fall, other parts have an average supply, and others again may be favored with an abundant fall. In the basin of the Darling, excluding the hilly portion, the rain-fall is 12.81 inches. In the plains between the Lachlan and the Murrumbidgee it is 16.33 inches, and in the corresponding district between the Murrumbidgee and the Murray it is 14.56. These

rain-falls would be sufficient for ordinary crops of cereals if they came at proper periods, but the report of the commission admits that they do not. It says that as a rule in these districts when rain is most needed it comes in such small quantities as to be of little or no benefit to vegetation.

One of the most difficult questions with which Australians have to deal in connection with the subject of irrigation is the best means for the storage of water. There is no doubt that much of the rain-fall is of a temporary benefit only, on account of its tropical character, coming, as it does, in vast quantities at a time when it is not needed. The government astronomer states that rain fell to the depth of 10½ inches at Newcastle in less than two hours and a half, and that at the South Head, near Sidney, it fell at the rate of one inch per hour for more than twenty hours. The report of the New South Wales royal commission recommends the establishment of large reservoirs at the heads of the principal rivers and creeks, and the placing of movable weirs across others in time of flood. They also recommend the establishment of sluice-gates to prevent the return of water to the main stream. Mr. Harold, in commenting upon the report of the commission, says that whatever is done for irrigation should be done by huge artificial water conservations in the mountains and by artesian and other wells. He says occasionally, in times of floods, water might be preserved, but it could not be depended upon. In conclusion he says that we should bear in mind that very fair crops can be grown over a large area in New South Wales without the aid of irrigation. He cites in support of this statement the fact that during the drought of 1886, one of the severest ever known, the average yield of wheat in these districts was ten and one-half bushels per acre. Mr. Harold says, however, that it is useless to think of irrigation for pastoral purposes in Australia, except upon a limited scale, as the cost would be too great. "It might answer," he says, "where land can be had at almost nothing, but where population increases the land will become more valuable, and it will be required to grow food for the people instead of grass for sheep."—*U. S. Consular Report, No. 79.*

WALLA WALLA'S CLIMATE.—The Walla Walla valley possesses a climate combining conditions the most healthful to the human body, and essential to the best development of agricultural products.

The altitude of the town of Walla Walla is 1,000 feet above sea-level; the average annual rain-fall is 17.5 inches, both altitude and rain-fall increasing rapidly as the valley is ascended. The mean annual temperature is 53°, as deduced from observations of Mr. Isaac Straight, for fifteen years. This is also the mean temperature of Washington City, and Baltimore—places with very pleasant climates. The highest temperature, 105°, in August, 1885; the lowest, 29° below zero, in January, 1875. This was the extreme cold of the period of fifteen years; the next lowest being 20° below zero, in February, 1883.

The warm days of summer are followed by cool nights, which render a pair of blankets essential to comfort while sleeping. The cold of winter is accompanied by calms and a dry atmosphere which rob the cold of all its keenness. The cold spells last but a few days. No seven consecutive days on record would have a mean temperature below zero. The warm Chinook winds, with intervals of a few days, or a week, prevail during the winter, carry off the snow, and diffuse a springtime warmth all over the valley. During the winters of '86-7 there were no fewer than fifty days between November 8th and March 14th upon which this wind, with a temperature between 48° and 65°, prevailed. This is the only winter for which there is a record of the Chinook winds.

Destructive winds are unknown; winds of even thirty miles per hour are rare, and a velocity of forty comparatively unknown. Thunder-storms average four or six during the year, are of very moderate character, and seldom more than distant lightning.

The humidity of the air is low, fifty-seven per cent. for '86, the only year for which there is a record. The dry air is a very healthful one to persons with weak lungs.

The rain-fall, annual average 17.5 inches, occurs during the nine months between September 15th and June 15th. The re-

maining three months may be considered as entirely dry, no rain, other than an occasional sprinkle, ever falling. The rainfall increases rapidly as the altitude of the valley increases; in some localities the average is from twenty-six to thirty inches annually. This precipitation is abundantly sufficient for all growing crops. No irrigation is used except by gardeners for the special forcing of market products.—H. S. BLANDFORD, in *The Northwest Magazine.*

IZALCO.—A San Salvador correspondent of *The San Francisco Alta California* writes: Your Central American correspondent was recently at Izalco, the most active and most attractive of the volcanoes of Central America. It never harms anybody. There is a church at its base, its buttressed walls quite eighteen feet thick. It has stood the rockings and racket of daily quakes through 180 years. Three great bells, each weighing 1,000 pounds, and constituted quite one-half of silver, are suspended in the church-yard. They are often tolled by Izalco when the jolly mountain is in a rollicking good humor, or perhaps when it is "colicky." Its explosions occur at intervals of from three to five and fifteen minutes. Now and then the great vents for explosive forces within are hermetically sealed for five or six hours, and even longer. Then the country has ague fits and San Salvador is shaky, and the prescribed path of earthquakes, which is about twenty-five miles wide, is "rattled." This, too, is the width of the coal-beds along this route of earthquakes. Beneath the coal is the river of oil that is on fire at Izalco. There coal, oil, and a stream of water meet. Each explosion of the mountain emits two columns, one of black smoke from the burning oil, the other of white steam from Rio Caliente, which runs out from beneath the mountain and crosses the railway five miles from the volcano. The water is so hot that it peeled the hair off my mule's legs that crossed it a few days ago. When an explosion occurs in Izalco, not only do these two columns of steam and of smoke rise up among the clouds, but great stones and ashes and scoriæ and vast volumes of lava are emitted. The greater portion of all this measureless volume of earthy mineral

substances falls back into the crater, closing it and resting on it as a mighty valve. Great masses of earth and stone fall in from the interior of the mountain side, and then the valve is heavier and deeper and broader than usual, and the oil must burn longer, and greater and more resistless volumes of gas must be produced. The flames rage, the waters boil, gas and steam and smoke explode at last, and the country along the earthquake's or coal measure's route is rudely shaken, and the thunders of the universe are heard roaring through the vast distances in measurcless caverns beneath Izalco.

VERIFICATIONS OF WEATHER-SIGNALS for July, in Minnesota, were 77 per cent. for weather and 75 per cent. for temperature; for Eastern Dakota, 85 per cent. for weather and 88 per cent. for temperature. In Michigan the per cent. of verification for weather was 85.7 and for temperature 82.9.

IOWA WEATHER.—July, 1887, was very hot, fine dry weather, with southerly winds or calms prevailing. Thunder-storms and rains were frequent, but generally very local.

The mean temperature of the air was three and a half degrees above normal. During the past forty-eight years, July has but once been hotter in Iowa, namely in 1868. July was nearly as hot as this year in 1864, '54, and '45; in 1886, '81, and '78 it reached to within one degree of this year's temperature.

Although the heat was very protracted, and on several days reached close up to the highest ever observed, we have heard of only one case of fatal sunstroke in Iowa. In other parts of the United States fatal sunstrokes were numerous, especially on Sunday, the 17th. The reason of this immunity from fatal effects of heat in Iowa is the present great dryness of our air; the relative humidity on the hottest days came down to thirty per cent. Hence the apparently strange fact that threshing machines were kept running in Iowa while the thermometer ranged high in the nineties, without fatal effects to man or beast.

The rain-fall was generally considerably below normal in

amount, and on the whole came in local showers only. It rained in the state on twenty-one days, or on two out of every three days, so that the rain frequency for the entire state appears high. But on only eight of these days did the rain extend to about half of the stations reporting, and on no day did it rain throughout Iowa. The only parts of Iowa which received the normal amount of July rains form a belt from Sac over Hancock to Mitchell county, and a large area covering most of Buchanan, Benton, Linn, Iowa and Johnson counties, where from four to six inches of rain fell. From these regions of full normal rainfall, the amount diminishes in all directions, remaining fairly satisfactory in the north and east, and running down to less than two inches in southern and middle central parts of Iowa. In portions of south-eastern Iowa, even less than one inch fell.

Flowing water, and especially ground water, has been very low. Creeks that never have been known to be dry before, have become so now, so that it is often very difficult to provide water for stock. This is due to the drouth of last year having left the ground dry; this year's rains, if no drouth had preceded, would have been sufficient to maintain a fair supply of water in creeks and springs. GUSTAVUS HINRICHS.

MICHIGAN STATE WEATHER SERVICE.—This service, commenced in December, 1886, is intended to determine the climatic features of Michigan and publish monthly the reports of the voluntary observers, about 40 in number. The regular observations are taken at 7 A. M., 2 P. M. and 9 P. M., *Central standard time.* [The observations for the Michigan State Board of Health are, we believe, taken at the same hours, but in *local* mean time.] Since February of the present year monthly reports of the service, giving summaries of the various meteorological observations, have been published in connection with the Michigan Crop Report. The first number contains, besides the usual data, a description, with illustrations, of the weather signals which were first adopted by this service in December, 1886; the U. S. Signal Service introduced the same system of signals in March of the present year. The succeeding numbers

contain, in addition, the special monthly bulletin of the U. S. Signal Service. The work seems to be conducted with vigor, under the able direction of N. B. Conger, Serg. Sig. Corps, U. S. A.

THE GREAT WALLED RIVER.—In the Bulletin of the American Geographical Society, Vol. XIX, No. 2, Mr. Dellenbaugh gives a very interesting account of a trip which he, in company with ten other men, made down the Rio Colorado Grande. The first and only living beings who had ever passed entirely through the Grand Cañon were Maj. J. W. Powell and five companions; this voyage turned out so disastrously that the data collected were of little value. Soon afterwards Maj. Powell obtained an appropriation from Congress to meet the expenses of a second voyage. This party, in three boats, pulled out of Green River City in April, 1871, and after many exciting experiences reached the mouth of the Para in October of the same year, at which point the party left the boats for the winter. In August of the following year the journey was resumed in two boats carrying seven men. To show that the journey through the Grand Cañon, a gorge nearly 300 miles long and more than a mile deep, was full of the most exciting experiences and danger, a single extract of an almost every-day experience will suffice:

"About eight o'clock in the morning (Sept. 3) we started to run a rapid, of which no good view was obtainable, though we climbed high on the rocks. No sooner were we in the swift water above it than the dangerous character of the place was apparent. It was impossible to avoid going over. The boat gave a single wild leap, and then deluge after deluge rolled over us. A huge wave struck the boat a hard blow on the port bow, and with a quick careen she turned upside down. I grasped impulsively for something to hold on to as I felt myself going down, and was fortunate enough to clutch a spare oar fastened to the outside of the boat. I pulled myself up and glanced around. Not a soul was visible. There was the boat, bottom up; there was the receding rapid; there was the dark bend below; and there were the black walls shutting all in; a scene of the wildest grandeur and desolation, with the upturned boat floating along like a worthless, insignificant chip. The other boat had not yet come in view. My companions soon rose to the surface close by, though to me those few lonely seconds seemed minutes."

The party left the boats at the mouth of the Kanab Cañon, having reached, by water alone, a point 4,700 feet lower than the starting point. There is almost no vegetation present, and for miles in many places it is impossible to effect a landing, the walls rising perpendicularly from the water's edge. It is a curious fact that this river actually cuts in two a mountain, and passes through plateaus the general surface elevation of which is greater than surfaces nearer the source of the river, plainly showing that there has been a *gradual* upheaval of the rocks through which the river flows.

THE BLUE HILL METEOROLOGICAL OBSERVATORY publishes the results of its observations for 1886 in a quarto pamphlet of 54 pages, with plates giving copies of the automatic records of the various instruments. The instrumental outfit of the observatory is very complete; it has evidently been the object of much time and care to make it as complete as possible. The records are generally automatic, and in some cases they are duplicated by instruments of different patterns.

While it has evidently been the care of the proprietor, Mr. A. L. Rotch, to make the observatory as complete as possible, the direct oversight of the observations has been in the hands of another competent meteorologist, Mr. H. Helm Clayton, whose enthusiasm and care in his chosen field of work are well known to our readers. Between the director and assistant it is to be expected that thoroughly good work would be done, and this publication shows that such has been the case.

This observatory is a private one, established by Mr. Rotch in 1885. The current expenses, amounting to $2,500 per year, are entirely borne by him. It is situated on Great Blue Hill, near Boston, at an elevation of 635 feet, the highest point within 10 miles of the Atlantic from Maine to Florida. It overtops the surrounding summits by over 100 feet, so that its exposure is free in all directions. The building was designed for the purpose, and was constructed at a cost of $3,500. In its construction especial precautions were taken to insure solidity; it is of stone, the walls are 20 inches thick, and the roofs are securely

anchored to them. Notwithstanding the thickness of the walls, it has been found, curiously enough, impossible to make them impervious. Though several coats of marine varnish have been applied, rain in a high wind is driven through the stone,—probably through minute cracks which it must contain. An auxiliary station was established July 1, 1886, at the foot of the hill, 440 feet below the observatory and three quarters of a mile distant. A comparison of the records of the two stations has already brought out several anomalies in temperature and precipitation. Two other stations send monthly reports to the observatory.

This observatory is a notable case of the value of private enterprise in the advancement of such a science as meteorology. In such an observatory as this not only may the equipment be unusually excellent, but greater care can be given to the observations and their reduction, and the work can be easily directed to definite questions which need especial study. This observatory is especially devoted, as we understand it, to the study of high level meteorology. The contributions it has already made are of decided value, and they will grow increasingly valuable as the observatory grows in age. H.

OUTFLOW OF AIR UNDER FALLING RAIN.

It has been generally assumed by students of meteorology that falling rain-drops carry with them and compress before them the air, which, flowing out, produces at times, in front of a thunder-storm, a wind velocity of forty and even fifty miles per hour. This theory has been advanced in Johnson's Encyclopædia (see article "Lightning," p. 34). There seems to have been no careful computation made on the subject, and it may be worth while to examine the matter in detail. Let us first determine an approximate value for the limiting velocity of rain-drops falling in a resisting medium. Deschanel says, "the limiting velocity is that at which the resistance encountered from the air is exactly equal to the weight of the body." In Price's theory of projectiles there is the following formula: $v = \frac{\sqrt{g}}{k}$ in which v = velocity in centimetres per second, g =

force of gravity, or 981 centimetres, and k is the resistance factor, which increases directly as the density of the medium, directly as cross section of projectile, and inversely as mass of the body. In the case of a drop of water

$$k = \frac{.001293 \times \text{cross section}}{\text{volume of drop}}$$

in which .001293 = density of air, water being taken as unity. Since the total available surface for resistance on a sphere is about equal to the greatest circle that may be cut from it, we find $k = \frac{3 \times .001293 \times 4\,\pi\,r^2}{16\,\pi\,r^3} = \frac{.001293 \times 3}{4\,r}$, in which r = radius of sphere. Substituting this value of k in the formula, we have $v = \frac{981 \times 4\,r}{\sqrt{.001293 \times 3}} = \sqrt{.1011601 + r}$. If a rain-drop be regarded as a sphere of water .2 inch (5 millimetres) in diameter, its limiting velocity by the above formula would be 5.03 metres per second, or 11.3 miles per hour. It is safe to assume that, under no possible combination of circumstances, can the velocity of the outflowing air be greater than that of the drop, and a little consideration will clearly show that it must be vastly less.

HYPOTHETICAL CASES.

A. In order to determine the probable effect of an aggregation of drops, we may take the most extreme case possible, and reason from that as to what the limiting effect would be. The formula introduced above applies strictly only to spherical or very nearly spherical bodies, and these of small dimensions. Yet it may be said that if applied to extended flat surfaces it will show, if anything, too great a velocity; hence, we shall never get too small a result in the latter case. Let us suppose continuous strata of water of different thicknesses so evenly balanced that each will fall through the air perfectly horizontal, and at the same time intact. We may determine the limiting velocity of each stratum as follows: In the above formula, in the case of flat surfaces,

$k = \frac{.001293 \times a}{a \times d}$ in which a = area of surface in square centimetres, and d = depth or thickness of the stratum in centimetres. It is easy to see that the area cancels out of this expression, which shows that, if the formula could be applied strictly to the case in hand, the velocity of fall would be independent of the extent of surface. Entering the formula with different thicknesses of the stratum, the following table is obtained. For comparison, the velocity of a sphere having a diameter equal to the thickness of stratum, is added:

Depth of strat'm.	Velocity.		
	Metres per sec.	Miles per hour.	Sphere. Miles per hour.
.1 cm.	2.8	6.1	5.1
.2 "	3.9	8.8	7.2
.3 "	4.8	10.7	8.8
.4 "	5.5	12.4	10.1
.5 "	6.2	13.9	11.3
.6 "	6.7	15.1	12.4
.8 "	7.8	17.4	14.3
1.0 "	8.7	19.5	16.0
1.5 "	10.7	23.9	19.6
2.0 "	12.3	27.5	22.6
2.5 "	13.8	30.8	25.3

It may be claimed that as the volume of the cylinder increases much faster than its surface, more air must necessarily pass from beneath, in proportion to the surfaces, in a large mass than in a small one; hence, the velocity of the outflowing air may become greater than that of the falling body; but it should be noted that, as the volume increases, the resistance of the air also increases; hence, a velocity greater than that of the falling body seems impossible. It is extremely difficult, without experiment, to calculate just what effect such a falling stratum would have on the air beneath it. From the somewhat analogous case of a parachute, we would anticipate that the resistance to fall would become very much greater in proportion to the extent of surface; *e. g.*, a surface a square mile in extent would acquire

only a very small velocity, at all events much less than that of a sphere having a diameter equal to the thickness of the stratum. It is evident, however, that the above conditions never can take place in nature.

B. If rain fall at the rate of four inches (102 mm.) per hour (which is a large estimate), then 20.4 layers of rain-drops five millimetres thick would fall in the hour. Since the extreme velocity for the rain-drop would be 11.3 miles per hour, as already shown, it is plain that the different layers would be less than .5 mile apart. Now, if we consider the depth of the outflowing air as about .1 mile, and the diameter of a circular falling layer as two miles, the total amount of air to be moved would be $\pi r^2 \times h$, or $.5\,\pi$, and the cross section of the escaping air would be $2\pi r \times .1 = .2\,\pi$. The length of the prism of escaping air would be $\frac{.5\,\pi}{.2\,\pi} = 2.5$ miles. But the length of time elapsing between the arrival of each layer at the earth's surface must be $\frac{60}{20.4} = 2.9$ minutes, and at the rate of 11.3 miles per hour, or .19 mile per minute, the total distance traversed by the wind could be only .55 mile, which is about one-fifth of 2.5 miles, as just computed, and we must consider that this difference is due to the resistance of the air and other considerations not introduced in the theoretical formula. If we assume an approximate velocity of four miles per hour for the moving air, we shall find the distance between any two layers .2 mile, and the mass to be moved $\pi r^2 \times .2$ just equal to that which flows out, or to $2\pi r \times .1$. Hence, it seems probable that under the conditions assumed above, of a *continuous layer* of drops five millimetres in depth and two miles in diameter falling freely in air, we could not expect a velocity greater than four miles per hour for the outflowing air.

ACTUAL CONDITIONS.

The number of drops per square foot of surface that fall each hour differs much in different storms, but we may make an estimate for the extreme case of four inches per hour. The vol-

ume of four inches of rain on one square foot would be 576 cubic inches; assuming the drops to be .2 inch (five millimetres) in diameter, their volume would be .0063 inch, and in 576 cubic inches there would be 91,429 drops; since the drops have a velocity of 11.3 miles per hour they would have to fall in single line about 7.8 inches apart to produce four inches of rain on a square foot. The velocity of air rushing out from under the drops could not be greater than that of the drops, and the size of the cylinder of air would be equal to the cross section of the drop. If we consider that all the air is to be moved uniformly, since the amount of space taken up by the drop is to the whole as .031 is to 144, we see that the relative amount of the total space covered by the drop is only $\frac{1}{4645}$; in other words, granting that a column of air having the cross section of the drop is propelled at the rate of 11.3 miles per hour, yet, if the force could be distributed over the whole space, it would produce a total velocity of the whole air at the edge of the falling rain of only $\frac{113}{46450}$, or .00243 miles per hour, or .0036 feet per second, which is entirely inappreciable. If the objection be raised that the above computation takes account of only the edge and not the interior of the storm, it may be said that it is difficult to see why we ought not to get the greatest velocity from this cause at the edge, and the effects in the centre of the storm can never be as great as at the edge. There are other considerations still which show that the actual result would be even less than this. There is a familiar laboratory experiment in which a vertical jet of water is made to carry at its top a wooden ball. Some physicists believe that the ball is kept from dropping because of a partial vacuum very near the jet which is produced by the rush of water through the air. Now, if this be so, it would seem that the tendency would be for the air to rush in behind the rain-drop, and hence the total effect of the fall of the air in front of the drop would be somewhat diminished by the above tendency. The problem is a very intricate one indeed, and the

above computation may need some modification after farther study, but it seems probable that we can safely say that no appreciable velocity of air will ever be produced by compression from falling rain. H. ALLEN.

July 22, 1886.

RECENT ADVANCES IN METEOROLOGY.

In the July number of the METEOROLOGICAL JOURNAL, page 116, Mr. Curtis seems much surprised at my using the expression, "weight of body in the sense of its mass." If I were even disposed to go into any discussion of the subject here, I would consider it entirely unnecessary after the somewhat recent and long continued discussion of it in *Nature*, in which a considerable number of physicists, about equally divided as to sides, took a part, and in which perhaps all the arguments of value on either side were advanced. I carefully read and studied the arguments on both sides, and then adopted the view of what I considered the stronger side. It is merely a matter of definition and of the sense in which the expression is most generally used. With a proper definition of the unit of measure, it can be used in either sense, but being used in two senses, whoever uses it in science must define how he uses it. Since we have to do only with mass and pressure, the use of the term should be excluded in science, as was suggested by one of the writers in the controversy referred to above, but it is so customary to use the expression "weight of a body in the sense of its mass" (the latter being determined by weighing or balancing the body against units of mass and so-called weight), that it would seem like a great innovation to exclude the use of the term.

In the review a considerable number of oversights and typographical errors have been found. This is always to be expected in first editions of works on complex and difficult subjects, but the number here is greater than it otherwise would have been if the work had not been done under the impression that it would be subject to a thorough revision before being printed, in which the errors would be mostly discovered. The understanding was that the manuscript, as finished, was to be used by Professor

Waldo in his lectures before the classes in the school at Fort Myer, and for this purpose several duplicate copies of the first part of the manuscript were made, but on account of the failure of Professor Waldo's health and the subsequent abolishment of the school, this plan was not carried out, and the manuscript was printed without any revision. It was also my intention to introduce a few expansions and explanatory clauses wherever Professor Waldo, in the study of the text, should think it advisable, and also to have him and the classes solve the examples and to give the correct answers for insertion in the text. But this part of the plan also failed, for the same reasons. It is still important to discover and to make a note of the errors, but it is to be regretted that this was not done before the printing.

On page 26 (equation 40) is an error not noted by Mr. Curtis. The value of r^1 should be 6634463 instead of 6364463, the error having been evidently introduced in copying by transposing the figures 6 and 3. The same value should be used in equation 48, but the term is so small that the error is of no consequence.

The constant in (49), 0.0000003, should be strictly just one-half of this, but there is no practical error introduced, since the tables are based upon the true constant.

The error of page 28, line 23, arose from thoughtlessly applying a negative logarithmic correction to a negative term in the expression.

There is an unfortunate confusion in the references to the tables here. When the appendix was prepared it was necessary to change the arrangement of the tables, and in correcting the references in the manuscript all were not found.

On page 28, line 25, Tables I and IV should read Tables I and VIII, and not Table I simply, as given by Mr. Curtis. The use of Table VIII in connection with Table I gives a result more accurate than that of the formula, in which Laplace's correction for moisture is introduced. This is imperfect, since it makes the correction negative for freezing temperatures, which cannot be. Table VIII represents more clearly the correction based upon Dr. Hann's formula expressing the relation between temperature and the average amount of moisture corresponding,

but this also makes the vapor correction negative for temperatures below —9° C., and so a small correction is introduced into the table for this defect. It would be better to make the last sentence in the paragraph read as follows: Also 4.264855 + log $[1 + .002\ (t' + t)]$ is given by Tables I and VIII by deducting 0.51703.

The formulas on this page are not of much use, since we have to do mostly with the relation between B and P^1 and not P and P^1, and hence the tables have been adapted to the former, and therefore require the correction in the less frequent case only.

The origin of the error on page47 is in the equation (75) in which the numbers should have contrary signs, since the value of Q increases as that of q decreases. WM. FERREL.

KANSAS CITY, August 14.

OPENING AND CLOSING OF NAVIGATION AT ROCHESTER.

The following will be of some interest for future reference. The first table is from a newspaper clipping which we found in an old Detroit meteorological register belonging to Dr. Geo. Duffield. The second table we owe to the kindness of Dr. L. Swift, Director of Warner Observatory, at Rochester:

FROM DR. GEORGE DUFFIELD'S REGISTERS.

	Canal.		River.	
	Date.	Days Closed.	Date.	Days Closed.
1830	Dec. 17	123	Dec. 23	82
1831	Dec. 1	135	Dec. 5	111
1832	Dec. 21	126	Dec. 25	83
1833	Dec. 12	132	Dec. 13	73
1834	Dec. 12	125	Dec. 15	100
1835	Nov.30	135	Nov.30	125
1836	Nov.26	150	Dec. 7	111
1837	Dec. 9	121	Dec. 14	94
1838	Nov.25	127	Nov.25	120
1839	Dec. 16	137	Dec. 18	61
1840	Dec. 3	148	Dec. 5	109
1841	Nov.29	153	Dec. 19	47
1842	Nov.23	147	Nov.28	135
1843	Dec. 11	150	Dec. 10	98
1844	Nov.26	143	Dec. 17	68
1845	Nov.29	137	Dec. 3	105
1846	Nov.25	111	Dec. 14	115
1847	Dec. 21	121	Dec. 25	86
1848	Dec. 9	144	Dec. 29	78
1849	Dec. 5	147		

DR. SWIFT'S TABLE FOR THE CANAL.

Year.	Open.	Closed.	No. Days Open.
1840	April 20	Dec. 9	228
1	24	Nov. 30	221
2	20	28	222
3	May 1	30	214
4	April 18	26	222
5	15	29	228
6	16	25	224
7	May 1	30	214
8	1	Dec. 9	223
9	1	5	219
1850	April 22	11	234
1	15	5	235
2	20	16	239
3	20	20	245
4	May 1	3	217
5	1	10	224
6	5	4	214
7	6	15	223
8	April 28	8	225
9	15	12	242
1860	25	12	232
1	May 1	10	224
2	1	10	224
3	1	9	223
4	April 30	8	223
5	May 1	12	226
6	1	12	226
7	6	Dec. 20	229
8	4	7	217
9	6	10	218
1870	10	8	213
1	April 24	1	220
2	May 13	1	202
3	15	5	205
4	5	6	215
5	18	Nov. 30 (by ice.)	197
6	4	Dec. 1	211
7	8	7	214
8	April 15	7	237
9	May 8	6	212
1880	April 16	Nov. 21 (by ice.)	220
1	May 12	8	211
2	April 11	7	241
3	May 7	1	208
4	6	1	

SELECTIONS.

THE THEORY OF THE WIND-VANE.*

The common weather-cock, or wind-vane, is no doubt the oldest, as well as the simplest, of meteorological instruments. In its earliest use, as a popular indicator of the weather, erected at the summit of a flag-staff or a church-tower, or, in New England, forming the usual apex of the town liberty pole, the vane assumed the form of a cock, a fish, a trumpeter, or other ornamental device; but, with its application to accurate meteorological observations, these forms were replaced by simple plane plates, discs, or arrows, designed solely with regard to the mechanical action of the wind upon them.

The form in general use at present is that of an arrow with a double or spread tail. The first reference I find to the construction of a vane of this design is by the elder Parrot, (*Voigt's Magazin*, i, 1797). In order to diminish the continual oscillations to which the vane is subject during variable winds, he made a vane of two thin plates joined at one end at an angle of about 45°. This was used by the younger Parrot, in his well known expedition to the Caucasus in 1811, with Engelhardt. Similar vanes were soon introduced in other countries, and by 1840 were in common use by English meteorologists. With respect to the advantages of their use, Jelinek, writing in 1850, makes the following statement: "The English seek to obviate the disadvantages of the complete rotations by making the vane of two plane surfaces set at an angle to each other of generally about 22½°. They say that thereby the oscillations are smaller, and the complete rotations less frequent." Stating that experience shows this to be true, Jelinek adopted the same form for a self-recording anemoscope, designed as an improvement on that constructed for the Austrian meteorological service by Dr. Kreil in the preceding year, which, consisting of a single plane circular plate, had occasioned much difficulty by its frequent complete rotations.

*From the *American Journal of Science*, Vol. XXXIV, July, 1887.

While the spread vane has thus grown in favor, the angle of the wings has gradually been reduced. Starting with an angle of 45°, as made by Parrot in 1800, the angle in 1850 was generally 22½°, and at present even a smaller angle is frequently used. In practice the surfaces are made with a slight curvature, so that the actual angle made by their tangents increases from zero at the vertex, to 30° or more at their extremities. *Voigt's Magazin*, in which Parrot's description of his vane appeared, is not accessible to me, and his reasons for adopting 45° are not given by reviewers. Similarly, I have found no explanation of the reason for adopting any of the smaller angles subsequently used. The following analysis has therefore been made, in order to find definitely what advantages the spread vane possesses, as compared with a straight vane of the same length and shape, and at what angle the wings should be set to secure the greatest efficiency.

The wind vane, its surfaces assumed to be plane, is a case of a body immersed in a fluid current, whose resultant pressure is normal to the exposed surface, and proportional to some function of the angle of incidence. If a be the angle between the surface normal and the perpendicular to the direction of the current, the old theory of the resistance of fluids made the resultant normal pressure upon the surface proportional to sin a. This was based upon the theory that the amount of fluid impinging on a unit of surface is proportional to sin a, and the normal component of pressure exerted also proportional to sin a; or again, the velocity of the fluid resolved perpendicularly to the surface being v sin a, the resultant force exerted against the surface must be proportional to $v^2 \sin^2 a$. But all this reasoning is now known to be worthless. Experiment shows that the resistance is much more nearly proportional to the sin a than to its square. Colonel Duchemin* was one of the first to give a more accurate formula based upon the results of experiments. He found that the pressure on a plane moving obliquely in a fluid may be represented by the following empirical formula:

*Duchemin: Recherches experimentales sur les lois de la resistance des fluides, Paris, 1842.

$$N = P. \frac{2 \sin a}{1 + \sin^2 a}$$

in which P is the resistance to a plane moving normally. Later experiments, made for the London Aeronautical Society in 1872, indicate that for large values of a the observations would be better satisfied by making the denominator $1 + \sin a$ instead of $1 + \sin^2 a$. This change has also received a theoretical confirmation. By the analytical method of Kirchhoff and Helmholtz, Lord Rayleigh has derived a formula for the case of a blade-shaped surface which makes the pressure per unit of area

$$\frac{\pi \sin a}{4 + \pi \sin a} \rho v^2.$$

For small values of a neither of these formulæ differ much from $\sin a$, and for the purposes of this paper it will be assumed that this latter relation holds good; therefore the normal pressure on the surface of the vane tending to produce rotation will be proportional to the sine of the angle between the surface and the wind direction.

Let $(1 + n)\ P$ be the total effective pressure on a *straight vane* when at right angles to the wind, where n takes account of the diminution of pressure on the sheltered side. The value of n varies with the angle of obliquity in some ratio not yet fully known, but, for its first approximation may be assumed, like the pressure on the exposed surface, to be proportional to the sine. On these assumptions the gyratory force tending to restore the equilibrium of the vane will be, for an angle ν between the vane and the wind direction, proportional to $(1 + n)\ P \sin \nu$.

For a *spread vane*, let ε be half the angle between the two wings and ν the angle between the medial line of the vane and the wind direction. If ν be less than ε, the wind will act on both wings in opposite directions, but when ν is equal to or greater than ε, the wind will strike only one wing as in the case of a straight vane. Therefore, to obtain a measure of relative sensitiveness, we must compare the gyratory force acting in each of these two cases with the corresponding force acting on a straight vane. For simplicity, suppose the air between the wings to be

unaffected by the wind, as would be the case if the space were entirely enclosed.

1. When $\nu < \varepsilon$. The gyratory force is proportional to P [sin $(\varepsilon + \nu)$ — sin $(\varepsilon - \nu)$] = $P \sin \nu .2 \cos \varepsilon$, in which, for all ordinary angles of the wings, 2 cos ε may be put equal to 1.9. To compare this expression with $P \sin \nu (1 + n)$, the expression above given for the corresponding gyratory force acting upon a straight vane, we must know the approximate value of n, which varies with the size and shape of the plate. Experiments on normal planes of small size give values of n ranging from 0.2 to 0.86; for surfaces as large as ordinary wind vanes, the upper limit of n can hardly be as great as 0.5 and probably is less. With this value, the ratio of the gyratory force acting on the straight vane to that acting on the spread vane, when $\nu < \varepsilon$, is

$$1.5 : 1.9$$

2. When $\nu =$ or $> \varepsilon$. The wind strikes the exposed surface at an angle $\nu + \varepsilon$ and passes the sheltered surface at an angle $\nu - \varepsilon$.

The total gyratory force, therefore, will be

$$P \sin (\nu + \varepsilon) + n P \sin (\nu - \varepsilon).$$

Comparing this expression with $P \sin \nu + n P \sin \nu$, the corresponding gyratory force upon a straight vane, the first term is seen to be larger, and the second term smaller, than the respective terms of the latter formula.

If 0.5, the maximum value of n, be substituted in these formulæ, the difference between the two forces will be

$$u = \tfrac{1}{2} \sin \varepsilon \cos \nu - \tfrac{3}{2} (1 - \cos \varepsilon) \sin \nu,$$

which is the excess of the force upon the spread vane over that upon the straight vane. For all values of ε less than 41.4° this excess is positive and has its greatest* value when $\nu = \varepsilon$; with the increase of ν, the excess diminishes and becomes 0 at different points, depending on the value of ε, thus

* By an analytical investigation of the nature of u considered as a function of the two independent variables, ν and ε, it appears that this function has no critical value for ranges of ε and ν between 0° and 90°; but the greatest positive value of u (not a critical value) will occur when $\nu = \varepsilon$, the limiting value of ν under the present case.

for $\varepsilon = 10.°$ the excess vanishes for $\nu = 75.3°$
$\varepsilon = 20.$ " " $\nu = 62.1°$
$\varepsilon = 30.$ " " $\nu = 51.2°$
$\varepsilon = 41.4$ " " $\nu = 41.4°$

For a smaller value of n, the excess would vanish at larger values of ν.

Consequently, for all moderate values of ε and ν when $\nu < \varepsilon$, as well as when $\nu > \varepsilon$, the gyratory force acting on the spread vane is greater than that on the straight vane.

If a perfectly sensitive vane be defined as one that instantly responds to the slightest change in the direction of the wind, that vane upon which the winds exert the greatest gyratory force will be the most sensitive, supposing the vanes all have the same friction. The increased sensitiveness accruing to the spread vane from its greater gyratory force is diminished, and, for large values of ε, may be quite overcome by its greater lateral friction, due to that component of the wind pressure which passes through the axis transversely. This component is proportional to $\sin^2 \varepsilon$, nearly, and so its effect, which is small and negligible for small values of ε, increases rapidly and becomes an important factor for values of ε greater than 20° or 25°. This lateral friction, therefore, constitutes a condition requiring the angle between the wings to be small. A further indication as to the angle at which the wings should be set for maximum sensitiveness is found by an analysis of the expressions given above for the gyratory force.

1. When $\varepsilon =$ or $> \nu$. Place $\varepsilon = \nu + a$; then

$$2 \sin \nu \cos \varepsilon = 2 \sin \nu \cos (\nu + a).$$

Noting that $(\nu + a)$ must always lie in the first quadrant, this expression has its greatest value when $a = 0$, *i. e.*, when the half angle of the wings is not larger than the angle of the wind's deviation.

2. When $\varepsilon < \nu$. Examining the expression for gyratory force, $\sin (\nu + \varepsilon) + n \sin (\nu - \varepsilon)$, to find a critical value, it appears that the function is a maximum when $\tan \varepsilon = \dfrac{1-n}{1+n} \cot \nu$.

Making $n = \frac{1}{2}$, as before, $\tan \varepsilon = \frac{1}{3} \cot \nu$. For all values of ν up to 30°, this makes the corresponding value of ε to be greater than ν, which for the present case is an impossible value; but for this range of ν, from $\nu°$ to 30°, the *greatest* value of the function (not a *critical* value) will occur when $\varepsilon = \nu$. For values of ν above 30°, the value of ε giving a maximum diminishes downward from 30°, and for $\nu = 90$ becomes 0. Consequently the best values for ε for deviation of the wind below 30° will hold good also for deviations greater than 30°. The conclusion, therefore, is that, for maximum sensitiveness, the half angle of the wings should be the average angle through which the wind makes sudden deviations, this average being taken from 0 to 30°.

The question of the relative stability of a spread and straight vane remains to be discussed. That the continual oscillations of the wind vane are diminished, was the advantage claimed by Parrot for his spread vane, and has been the justified claim of his followers. Given two vanes of the same moment of inertia, for slowly shifting winds, the oscillations of the spread vane will be smaller than those of a straight vane, for, being more sensitive, it responds more quickly to any gradual change in wind direction, and, therefore, has a less amplitude of oscillation, and will sooner come to rest. When the wind suddenly changes direction through a considerable angle, the straight and spread vanes start out with the same angle of deviation from the new direction. The following analysis shows that, in this case also, the spread vane comes sooner to rest. If v be the velecity, r a constant depending on the length of the vane, ν the angle between the direction of the wind and the axis of a straight vane, the resultant relative velocity, R, of the wind and the vane will be the third side of a triangle of which two sides are the velocities of the wind and vane, and $90° - \nu$, their included angle.

Whence $R^2 = v^2 + 2\, v\, r \dfrac{d\nu}{dt} \sin \nu + \left\{ r \dfrac{d\nu}{dt} \right\}^2$, $\dfrac{d\nu}{dt}$ being nega-

tive or positive, according as the motion of the vane is with or against the wind. This resultant makes an angle φ with the vane such that

$$R \sin \varphi = v \sin \nu + r \frac{d\nu}{dt},$$
$$R \cos \varphi = v \cos \nu;$$

The effective force tending to turn the vane, which is proportional to $v^2 \sin \nu$ when the vane is at rest, becomes $R^2 \sin \varphi$ when the vane is in motion. Considering the motion when ν and $\frac{d\nu}{dt}$ are so small that we may neglect the square of $\frac{d\nu}{dt}$ and the product, $\sin \nu \frac{d\nu}{dt}$,

$$R^2 \text{ becomes } v^2, \text{ and } \sin \varphi = \sin \nu + \frac{r}{v} \cdot \frac{d\nu}{dt},$$

$$\text{Whence } R^2 \sin \varphi = v^2 \left\{ \sin \nu + \frac{r}{v} \cdot \frac{d\nu}{dt} \right\}.$$

Let I be the moment of inertia of the vane around its axis, ρ the air density, A the surface of the vane, $f_0(P)$ the pressure of a wind of unit velocity on a unit surface under a standard density of the air ρ_0, and r the distance of the point of application of P from the axis. Then the differential equation of motion for a straight vane will be

$$\frac{d^2\nu}{dt^2} + Kv^2 \left\{ \sin \nu + \frac{r}{v} \frac{d\nu}{dt} \right\} = 0$$

$$\text{where } K = \frac{\rho A f_0(P) \cdot r}{I}.$$

When ν is small, $\sin \nu$ may be replaced by ν, and simplifying the constants by making $Kv^2 = \omega^2$, and $Krv = 2k$ the equation becomes

$$\frac{d^2\nu}{dt^2} + 2k \frac{d\nu}{dt} + \omega^2 \nu = 0.$$

This is the equation of a circular pendulum in a resisting

medium where the resistance varies as the velocity. The general integral of this equation takes three forms according as $k^2 - \omega^2$ is positive, negative, or vanishes; a numerical evaluation shows that it is always negative, for which case, the integral becomes

$$\nu = ae^{-kt}\left\{\cos ht + \frac{k}{h}\sin ht\right\}.$$

where a is the greatest value of ν and $h^2 = \omega^2 - k^2$.

For a *spread vane*, where the half angle of the wings is greater than the deviation of the wind, the wind acts on both wings at once in opposite directions, and the resultant pressure will be

$$\sin(\varepsilon + \nu) + \frac{r}{v}\frac{d\nu}{dt} - \left\{\sin(\varepsilon - \nu) + \frac{r}{v}\frac{d\nu}{dt}\right\}$$

in which $\frac{d\nu}{dt}$ is to be taken with opposite signs in the two terms, and the expression reduces to

$$2\sin\nu\cos\varepsilon + 2\frac{r}{v}\frac{d\nu}{dt}.$$

Using the same notation as in the previous case, and making $2\cos\varepsilon = 1.9$, which is approximately true for all ordinary cases, we have the equation

$$\frac{d^2\nu}{dt^2} + 4k\frac{d\nu}{dt} + 1.9\,\omega^2\nu = 0. \quad \text{Making } h_1^2 = 1.9\,\omega^2 - 4k^2,$$

$$\nu = ae^{-2kt}\left\{\cos h_1 t + \frac{2k}{h_1}\sin h_1 t\right\}$$

$$\frac{d\nu}{dt} = -a\cdot\frac{h_1^2 + 4k^2}{h_1}\cdot e^{-2kt}\cdot\sin h_1 t.$$

$$\frac{d\nu}{dt} = 0, \text{ when } t = 0,\ t = \frac{\pi}{h_1}\ t = \frac{2\pi}{h_1}, \text{ etc.}$$

Substituting these values of t in the preceding equation for ν, the amplitudes of vibration become successively

$$\frac{-2k}{h_1}\pi \quad \frac{-4k}{h_1}\pi$$
$$a, al \quad , ae \quad \ldots\ldots$$

Similarly, the amplitudes of vibration of a straight vane are, successively,

$$\frac{-k}{h}.\pi \quad \frac{-2k}{h}.\pi$$
$$a, ae \quad , \quad ae \quad , \ldots\ldots$$

To determine the relative magnitude of the oscillation in these two cases, let us substitute for $\frac{2k}{h_1}$ and $\frac{k}{h}$ their original values,

$$\frac{2k}{h_1} = \frac{Kr}{\sqrt{1.9K - K^2r^2}}$$
$$\frac{k}{h} = \frac{Kr}{\sqrt{4K - K^2r^2}}$$

If it be desired to take account of the diminution of pressure on the sheltered side of the straight vane, the value of K is not the same for both vanes, but will become so by multiplying K in the equations of the straight vane by the factor $1 + n$. Making this correction, $\frac{k}{h} = \frac{Kr}{\sqrt{\frac{4}{1+n}.K - K^2r^2}}$. For all possible values of n, $\frac{2k}{h_1} > \frac{k}{h}$, and, consequently, at any time t, the amplitude of oscillation of the spread vane, will be less than that of the straight vane, and so the former will sooner come to rest.

This difference in amplitude of oscillation is least when K^2r^2 is negligible in comparison with $1.9K$, in which case the difference between the amplitudes of oscillation is determined by the ratio $\frac{\sqrt{4}}{1+n} : \sqrt{1.9}$ as exponential factors in the expression

for the amplitude. This difference is increased by the term K^2r^3, r and K being constants depending on the length and surface of the vane.

The formulæ, therefore, show 1st, *that the oscillations of both vanes are smaller as the vanes are longer and larger;* 2d, *that the spread vane is always more stable than the straight vane;* and 3d, *that this advantage in stability is greater for long vanes than for short vanes, and is independent of the wind velocity.*

The above analysis obtains for a frictionless bearing. From the discussion of relative sensitiveness, we have found that with equal friction, a spread vane is more sensitive than a similar straight vane; consequently, for two vanes of equal sensitiveness, the spread vane will have the greater friction and will come to rest more quickly. GEORGE E. CURTIS.

THE FŒHN.*

[CONCLUDED.]

New Zealand has a pronounced Fœhn wind, there called a "nor'wester," descending from the lofty New Zealand Alps that border the western side of South Island, and blowing out to the broad Canterbury Plains. When this wind sweeps over the snow-fields and passes, the creeping cumulus clouds disappear as by enchantment, the sky becomes a deep clear blue, and the valleys are filled with a descending current of hot wind; the rising of torrents from the melting ice-streams shows the effect of the wind (J. v. Haast, Geol. of the Prov. of Canterbury and Westland, New Zealand. Christchurch, 1879, pp. 198, 199. See also a description by O'Brien in Haughton's Physical Geography, Dublin, 1880, p. 102.)

The Chinook wind of the northwest, along the eastern foot of the Cordilleran ranges, has lately again attracted the attention that Espy first gave it years ago (Fourth Med. Report, pp. 146, 147, 151). G. M. Dawson describes it as "a strong westerly wind, becoming at times almost a gale. . . . It is extremely dry, and, as compared with the general winter temperature, warm. Such winds

* From "Mountain Meteorology," *Appalachia*, Vol. IV, No. 4.

occur at regular intervals during the winter, and are also not infrequent in the summer; but, being cool as compared with the average summer temperature, are in consequence then not commonly recognized by the same name. When the ground is covered with snow, the effect of the winds in its removal is marvellous, as, owing to the extremely desiccated condition of the air, the snow may be said to vanish rather than to melt, the moisture being licked up as fast as it is produced" (Science, 1886, vii, 33). Professor Loomis notes the following case of rapid temperature changes at Denver, Colorado, on the plains just east of the front range of the Rocky Mountains: "An area of low pressure passed over San Francisco January 14, about 4 P. M. During the following night the centre passed near Salt Lake City, and at 4 P. M., January 15, the centre was near Leavenworth, having travelled about 1,400 miles in twenty-four hours. It was this storm which brought the air from the west side of the Rocky Mountains over to Denver. The vapor contained in this air would be mostly precipitated on the west side of the Rocky Mountains, so that it wound descend on the east side deprived of its moisture, and with a temperature above that which prevailed in the Salt Lake basin, on account of the latent heat liberated in the condensation of the vapor. . . . After the centre of low pressure passed Denver, the northeast wind returned and brought back the cold air which had constantly prevailed at stations not very distant. . . . Thus we see that in winter, during periods of extreme cold on the east side of the Rocky Mountains, when the temperature at Denver sometimes sinks more than 20° below zero, there prevails in the Salt Lake basin an average temperature of about 30°; and when by changes of atmospheric pressure this air is carried over the mountains it may reach Denver with a temperature of 50°, resulting from a precipitation of vapor on the mountains. We thus find a mass of air having a temperature of +50° in close proximity to a mass having a temperature of —20°, and by the movements of the atmosphere attending the progress of a great storm these different masses of air may be brought successively over the same station, causing a change of temperature of 50° in a single hour."

The following tables present numerical account of these changes from the same authority.

TEMPERATURE AND RELATIVE HUMIDITY, JANUARY, 1875.

Date.	Hour. (Washington Time.)	Salt Lake.		Cheyenne.		Denver.		Pike's Peak.		North Platte.	
		Temp.	R. H.	Temp.	R. H.	Temp.	R. H.	Temp.	R. H.	Temp.	R. H.
14	7 35	34°	61%	−11°	76%	−14°	100%	1°	100%	−13	74%
	4.35	43	50	− 1	68	− 4	64	8	100	− 6	61
	11.00	43	50	24	60	1	71	5	100	−11	76
15	7 35	32	84	28	67	43	21	6	100	− 8	79
	4 35	26	52	5	75	10	17	12	100	− 1	68
	11 00	23	73	− 6	61	13	44	10	100	− 4	64

Salt Lake, at the western foot of the Wahsatch Range, in the Great Basin, is constantly rather warm, and of ordinary humidity; Pike's Peak is cold and constantly at its dew point. North Platte, on the plains east of the mountains, is much colder, and distinctly dryer. Denver and Cheyenne are much alike in changes of temperature, as these stations are about equally distant from the eastern foot of the mountains; but Denver shows much the greater decrease in relative humidity, perhaps because the range west of this station is higher than farther north. The second table shows in greater detail how violent the changes of temperature were at Denver, and how completely they accorded with changes in the wind.

TEMPERATURE AND WIND, DENVER, JAN. 14, 15, 1875.

Date.	Hour.	Temp.	Wind.
14	2.43 P. M.	− 4	N.E.
	9.00	+ 1	N.E.
	9.15	20	S.W.
	9.20	27	S.W.
	9.30	36	S.W.
	9.35	40	S.W.
15	5.43 A. M.	43	S.W.
	13.30	52	S.W.
	12.30 P. M.	4	N.E.
	2.43	+10	. .

An observer, who was considered perfectly reliable, "says that between 11 A. M. and noon a thermometer fell from 58° to 22°

(that is, 36°) in five minutes" (*Amer. Journ. Science*, 1875, x, 12; 1880, xxii, 13, 14).

It is greatly to be desired that such studies as these shall be continued with the additional advantage of detailed and numerous local observations; and the subject can be highly commended to the Colorado Meteorological Association, whose stations will be developed where the American Fœhn can be studied to great advantage. The valley of Mono Lake, in California, east of the high Sierra, is probably visited by Fœhn winds of pronounced character; and the same should occur in Patagonia, along the eastern foot of the Andes. We see here the need of geographical exploration of meteorological phenomena.

W. M. Davis.

REDUCTION OF THE BAROMETER TO SEA-LEVEL.

At the meeting of the International Meteorological Committee at Paris, General Hazen, Dr. Wild, and the *Deutsche Seewarte* presented papers which contained so many points of interest that we reproduce them here. General Hazen's paper was as follows:

"In the matter of the reduction of the barometer to sea-level, I beg to submit the following considerations and to ask your kindly criticism and remarks.

"It would seem that the combination of observations on land with those on vessels, as long ago as 1857, rendered it necessary to give up the isabnormal lines (the isobarometric of Kämtz), and reduce all pressures to sea-level, and draw isobars which extended without serious error over low-lying portions of Europe and the adjoining ocean.

"The Signal Service in 1870, for the first time, had to confront the problem of drawing isobars on tri-daily maps (morning, afternoon, and mid-night), not only over oceans and lowlands, but inwards over high plateaus.

"In 18870 and 1871, this service endeavored to reduce each barometric observation to sea-level, by considering only the temperature and pressure prevailing at the station at the moment

of observation, and by assuming the average temperature of the column of air imagined below the station to be represented by the formula $t_0 = t_1 + \frac{h}{2c}$, where t_1, is the observed temperature, and $\frac{h}{2c}$ – the variation due to altitude. In any formula of this kind it is evident that by using t_1, there is a diurnal period introduced into the reduced barometer, which for high stations is very large and misleading. So troublesome was this, that already in January, 1872, this method was discontinued for the very highest stations (see Annual Report Chief Signal Officer, 1873, p. 373), and an annual constant was used for these, in order at least to be able to follow the local tri-daily changes in pressure.

"But for stations from 2,000 to 5,000 feet high, the original method still gave the same trouble, which was aggravated by a serious mistake in the use of a certain formula.

"In 1881, this office began using for all stations, a system of monthly constant reductions to sea-level based on the monthly normal pressures and temperatures. (See Annual Report, 1882, pp. 826–846). This method was adopted as a temporary device, and especially for certain financial reasons: it has features confessedly quite as objectionable as either of the above-mentioned methods.

"The arguments against any reduction of high stations to sea-level, and in favor of adopting a high plane, say 5,000 feet, to which both high and low stations should be reduced, are fully appreciated. They were, in fact, urged upon the attention of General Myer as early as 1872. This idea has been exemplified in the work of several European meteorologists, but as the reduction *to sea-level* still continues the most popular, improvements in its details have been constantly kept in view.

"An important modification is now proposed, which, while considered to have decided advantages, yet introduces so great a departure from existing customs, that, before adopting it, I desire a free expression of your own views as to its merits and defects, as I should prefer to make changes only in the direc-

tion of some method that would be generally acceptable to all meteorologists who have to prepare daily weather maps from telegraphic observations.

"It is proposed to utilize the fact demonstrated by several, notably Rühlmann, that the regular periodic diurnal change of temperature of the *mass of air* above or below any station, is so small as to be negligible in comparison with the periodic change at the station itself, and especially in comparison with the non-periodic changes that accompany the vertical and horizontal movements of large portions of the atmosphere. It follows from this, that the reduction to sea-level should be but little affected by diurnal temperature changes at the stations, but should depend principally upon the mean temperature of the air, whether the latter be a quiescent layer or a current flowing rapidly past the station. It is, therefore, necessary to devise such a combination of the local observations as will follow closely the large non-periodic changes of temperature, while at the same time eliminating the greater part of the periodic diurnal fluctuations shown by the station thermometers, and which are generally very local phenomena. It is not clear that we should attempt wholly to eliminate the diurnal fluctuations, as there must be a small period in the daily temperature of the mass of air, but, for the present, we may neglect this refinement.

"The special method by which the observer at any station may most easily obtain the mean temperature to be used in reducing the barometric observation, which he is then about to telegraph to the central station, must be left to the discretion of the respective national weather bureaus. It is sufficient to recognize the principle that he must use a temperature from which the diurnal periodicity has been largely eliminated.

"The following examples are suggestive:

"For the tri-daily observations and reports of the United States, use the mean of the temperatures observed at the given hour and the two preceding observations.

"In such a combination the diurnal variation is approximately eliminated, and the means follow the gradual non-periodic changes with considerable closeness. Thus, in the accompany-

ing chart of isobars for 7 A. M., February 4, 1883, Springfield, Ill., is in the front of an advancing mass of cold, dry air.

"Now, if we examine the record at this station, we find the temperature as given in the second column of the following table; in the third column is given, opposite each hour of observation, the mean of its own and the two preceding figures.

"These latter are seen to follow the gradual diminution of temperature and to be freed from diurnal change. They indicate approximately, therefore, the current temperature of the mass of air beyond the diurnal changes determined by the surface of the earth.

SPRINGFIELD, ILLINOIS.

Date.	Hour of Observation.	Observed Temperature.	Mean Temperature for computing Reduction to Sea-level.
1883, February 2	11 P. M.	32	—
" " 3	7 A. M.	33.5	—
" " 3	3 P. M.	26	30.5
" " 3	11 P. M.	15	25.
" " 4	7 A. M.	7	16.
" " 4	3 P. M.	8	10.
" " 4	11 P. M.	3	6.
" " 5	7 A. M.	−1	3.
" " 5	3 P. M.	11	4.
" " 5	11 P. M.	11	7.
" " 6	7 A. M	16	13.
" " 6	3 P. M.	26	18.

"For stations that telegraph but one observation daily, as in Europe, where the 7 or 8 A. M. (local time) observation is usually sent, it might be considered desirable to combine the morning temperature with that of the previous evening, usually 9 P. M., or to combine the morning minimum with the preceding maximum, or again to utilize to ordinary combination, $\frac{7+2+2+9}{4}$, or again simply correct the observed temperature for the average diurnal periodicity.

"In all these methods such combinations are to be chosen that the monthly mean of the individual reduced barometers will sensibly coincide with the mean actual pressure reduced to sea-level by using the mean temperature of the month.

In some such manner as above, the fictitious diurnal variation in the reduced barometer is approximately eliminated. We pro-

pose the above as the important point of the present communication; but in order to complete the reduction there remains still an important step, namely, to reduce the average temperature observed at the station to the mean of the air column.

"The rate of diminution of temperature with altitude varies both with the season and the geographical location, and the method of determining it must be left to each country to settle for itself. In any case it is not desirable to introduce too great refinements into this computation.

"Two methods of approximating to the mean temperature of the column of air which is assumed to replace the continents have been hitherto employed; one assumes that the vertical variation of temperature existing above the present continents can be carried down by extrapolation to the fictitious continent at sea-level; the other method assumes that the isotherms for those portions of the existing continents that are near sea-level can be prolonged by extrapolation underneath the highlands.

"The defects of the first method increase with the height of the plateau, the defects of the second method increase with the geographical extent of the plateau.

"For the United States, and, if we mistake not, for the whole world, the second method is to be preferred to the first.

"Following this second method, we have projected low-level isotherms of the United States for each month, and have extended them across the interior, and underneath the elevated plateaus of the western portion of the continent. These represent the surface temperature at an average elevation of 500 feet. A sample copy of such isotherms for January, 1883, is enclosed.

"The difference between the mean temperature at a high station and the corresponding low-level isotherm, gives a monthly series of approximate allowances for altitude.

"We have thus completely provided for the temperature of the mass of air under consideration, and the completion of the reduction to sea-level becomes sufficiently simple."

Dr. Wild presented the following paper from Dr. Leyst:

"In dealing with the subject of the reduction to sea-level of barometrical reading, we must first take into consideration the

conditions to be fulfilled by a method of reduction. When these conditions have been laid down, we can discuss the question of the choice of the method of reduction to be employed in the construction of the International Meteorological Tables for the Reduction of Barometer Readings to Sea-Level, proposed by the International Meteorological Committee.

"These conditions may be classified under four heads, according to the limits of accuracy required. Other considerations, such as facility in using the tables, the dispensing with logarithms, etc., can only be regarded as of secondary importance. In the construction of the tables, the difficulty of their calculation, which is done once for all, can be of no great matter. Facility in using the tables is certainly very desirable, but this should not be secured at the expense of their accuracy.

"The following are the four classes, according to the respective limits of accuracy:

"I. This class comprises the lowest standard of accuracy which is required, and this is admissible for synoptic charts, which aim only at representing the general conditions of weather, in its main features, at a definite epoch of observation, and are intended for reproduction in weather charts, weather bulletins, and newspapers, for the use of seamen, fishermen, and the sea coast populations.

"The value of such charts is only temporary. The limit of accuracy for such charts is 1 mm., and it is therefore of little importance what formula of reduction is used, provided this is not simplified too much.

"II. This class embraces all cases which demand greater accuracy, but yet may be reduced by a simplified formula, if the differences of height can be diminished by a suitable choice of the level for reduction. The smaller continental countries come under this head, as they publish synoptic charts for small areas, and their own stations are far more numerous than their foreign ones.

"Such charts are for the use of agriculturists, railway officials, and a limited number of readers.

"Here the limit of accuracy laid down under I. will suffice for

the foreign stations, while for the interior stations the reduction must attain the same degree of accuracy as is demanded of the observations themselves, namely, 0.1 mm.

"III. This class includes all cases in which synoptic charts possessing permanent scientific value are constructed, in order to serve as a basis for scientific researches. Any one who is using such charts as those prepared at the Central Physical Observatory at St. Petersburg, at the Seewarte at Hamburg, or those of the late Captain Hoffmeyer, cannot possibly examine each individual observation in order to test the accuracy of its reduction. In such cases it is only reasonable to demand that the accuracy of the observations should not suffer owing to inaccuracy in the method of reduction. It therefore follows that for Class III. the limits of accuracy in sea-level reduction should be 0.1 mm.

"For such charts the level of the sea is preferable to any other level chosen arbitrarily, owing to the great preponderance of observations from stations on the sea coast or on low-lying plains.

"IV. This class embraces all cases of means of pressure laying claim to greater accuracy, such as the means of many years, for the construction of normal barometric charts, in which the accuracy is set at 0.01 mm.

"For these the following conditions should be enforced:

"*In the calculation of the tables for the reduction of the barometer to sea-level intended for the International Meteorological Tables, such methods alone are admissible as will ensure an accuracy of—*

0.1 *mm. for the individual observations.*
0.01 *mm. for the means of many years.*

[TO BE CONTINUED.]

THE CLIMATE OF PEORIA.*

This abstract of meteorological observations is taken from three daily notations during 30 years, from December 1st, 1855,

* Read before the Peoria Scientific Association, September 24, 1886, by Fred Brendel, M. D., ex-President. From the *Bulletin* of the Scientific Association.

to November 30th, 1885. The observations were made at 7 A. M., 2 P. M. and 9 P. M., with a Green's cistern barometer and a number of centigrade thermometers made entirely of glass and suspended free in a shady place. It is the temperature of the atmosphere that should be measured, and not that of a wall, which being colder or hotter than the free air, influences the stand of the murcery by radiation. The maximum and minimum was noted every day, and the daily mean is calculated after the method adopted by the signal office from the sum of the three observations, that of 9 P. M. doubled and the whole divided by four. That gives about the true mean in the three winter months, when the minimum does occur at the time of the first, and the maximum at the time of the second observation, but not in the other nine months, particularly in summer, when the minimum right before sunrise is left out of the calucation. It would be better to take the maximum and minimum and two hours of equal distance, *i. e.*, 9 A. M. and 9 P. M. The degrees are converted into the old-fashioned Fahrenheit, to which the English conservatism is clinging so pertinaciously in spite of the better centesimal system, adopted by the rest of the civilized world, based on the freezing point of water, a body that does play the most important part in the economy of nature.

The rain and melted snow was measured by a rain-guage, consisting of a funnel and a corresponding graduated glass cylinder, each degree answering the hundredth part of an inch. The force of wind was not measured but estimated, and so cloudiness. The humidity of the atmosphere and the pressure of vapor is taken from the difference of the dry and wet bulb thermometer after the tables of Guyot. The place of observations changed during the 30 years several times, but only within a thousand feet of horizontal distance and thirty feet of elevation.

TEMPERATURE.

The mean temperature of the year is 52 degrees of Fahrenheit. It is higher than on other stations of Illinois of the same latitude, which is readily explained by the lower elevation above the sea level, being only 490 feet at the present place of obser-

vation, and in the midst of a large city. Even the little difference in elevation of the scarcely more than a hundred feet higher bluffs would show a several degrees lower temperature, as that part of the city is more exposed to the winds, particularly the northwest and west, which are the coldest.

The range between maximum and minimum is great, and the change of temperature is often very rapid. The highest temperature observed during the whole period of observations was 105 on the 31st of August, 1873, the lowest —27 on the 5th of January, 1884, a difference of 132 degrees. The greatest range in one month (January, 1874) was 87 degrees between 65 and —22, and the greatest range in 24 hours was observed in January, 1876, when the murcery went down 61 (28th, 2 P. M.) to 8 (29th, 7 A. M.) = 53 degrees, and the same range was observed 1881, in January, when the temperature fell from 34 (13th, 2 P. M.) to —19 (14th, 7 A. M.). Such daily oscillations are frequent, particularly in December, February and April, and even in July the greatest difference in 24 hours was 37 degrees.

The lowest daily mean temperature of the period in question, 20.7 (on the 8th of January), the highest 80.4 (16th of July).

Following the daily march of mean temperature. we commence with the 1st of December (the first day of the meteorological year) with a mean of 34. It keeps below freezing point from the 7th of December to the 24th of February (with the exception of two days, the 12th of December, with 32.8, and 22d of February, with 32.3); then it rises gradually (with exception of the 4th of March, with 30.7) during the month of March, keeps above 40 from the 26th of March, above 50 from the 17th of April, above 60 from the 7th of May, above 70 from the 5th of June, and reaches the maximum on the 16th of July; then descending gradually to 70 on the 8th of September, to 60 on 7th of October, to 50 on the 25th of October, to 40 on the 16th of November, and to freezing point on the 29th and 30th of November. That rising and falling of mean temperature is not quite continuous from day to day, but often oscillating, particularly in winter and summer; but taking periods of 10 days (decades) dividing each month in approximately three equal

parts, we find rise and fall continuous from the first decade in January = 22.6 to second decade in July = 78.3 and descending again to January in the following way:

Month.	1st decade.	2d decade.	3d decade.	Month.
January	22.6	24.5	25.8	24.5
February	26.	29.5	32.8	29.2
March	35.	37.	41.8	38.1
April	47.8	51.7	55.5	51.7
May	59.8	63.3	67.9	63.8
June	70.	73.	76.9	73.3
July	77.9	78.3	77.	77.7
August	77.	75.6	73.2	75.2
September	70.8	66.4	63.	66.7
October	59.7	53.5	48.5	53.7
November	45.5	38.8	33.9	39.4
December	32.2	28.6	25.3	28.6

That the maximum and minimum does not coincide with the summer and winter solstices is explained by the accumulation of heat during the summer months and in the negative during the winter months.

Comparing the result of 30 years with the march of temperature of a single year, we find the latter much more irregular. In 1858, after a very mild January, followed a severe February, and the first decade of March was colder than the first decade of January. In 1869 the first decade of February was the coldest of that winter, and March colder than January.

The mean temperature of Peoria is about the same as that of Paris in France under 48° 50′ N. L., that is 8 degrees farther north than Peoria. We find for spring and fall about the same temperature in both localities, but a great difference for summer and winter.

	Winter.	Spring.	Summer.	Fall.
Peoria	27.4	51.2	75.5	53.2
Paris	38.5	50.5	64.6	52.5
Difference	8.9	0.7	10.9	0.7

Rome, in Italy, about one degree farther north than Peoria, has a mean temperature of 60.8, in summer 74.3, in winter 50.

That makes the mean temperature of Rome about 9 degrees and in winter 22.6 degrees warmer than at Peoria, and the summer is nearly one degree cooler. These examples may be sufficient to show the difference of the climate of Western Europe and that of the central part of North America.

WINTER.

The three winter months together had the lowest mean, 20.7, in the winters from 1872 to 1873, and 1874 to 1875. Above freezing point was the mean of the winters 1862–63, 1875–76, 1877–78 and 1879–80; in all the rest it was below freezing point. The coldest January was that of 1857 (13.5), the coldest February 1875 (15.5), the coldest December 1876 (18.5). The warmest January was in 1880 (40.9), the warmest February 1878 (37.5), the warmest December 1877 (44.3). The coldest decade in January was 1864, 1st–10th (0.2), in February, 1875, 11th–20th (8), and in December, 1872, 21st–31st (8.8). The warmest decade in January was in 1864, 21st–31st (41.8), in February, 1871, 21st–28th (41.2), in December, 1862, 21st–31st (41.7).

When we call the three months December, January and February the three winter months, it is obvious that is mere theory. Practically winter is not restricted to those three months; there are no general limits which are good for every year. When we take freezing as a distinctive quality of winter we find its limits very variable in different years. The mercury is falling below freezing point in a period commencing on the 1st of October and ending on the 11th of May, so that the first frost days in the thirty years occurred between the 1st of October and the 12th of November, the last between the 25th of March and 11th of May. The longest of those periods was that in the winter from 1856 to 1857; the first frost was noticed on the 1st of October and the last on the 11th of May, a period of 223 days; the shortest was that from the 3d of November, 1877, to the 25th of March, 1878, a period of 143 days. The former contained 142, the latter only 51 frost days. Computing the averages, we find the first frost day to be the 17th of October, for the last

frost day the 17th of April, a period of 133 days, with 112 frost days and 48 days with a mean temperature not rising above freezing point.

SPRING.

The mean temperature of the three spring months together is 50.2. The lowest mean was observed in 1857, = 43, the highest in 1878 = 56.6. The coolest March was in 1867 = 29.5; the coolest April in 1857 = 39.9; the coolest May 1867 = 55; the warmest March 1878 = 50.5; the warmest April 1878 = 57.9; the warmest May 1881 = 71.4. The mean temperature of the decades are in March, 1st = 35; 2d = 37; 3d = 41.8. The lowest was the first in 1857 = 22.3; the highest the first in 1878 = 52.5; in April the 1st, 47.8; 2d, 51.7; 3d, 55.5. The lowest the 1st in 1881 = 32.7; the highest the 3d in 1879 = 66.2; in May the 1st = 59.9, the 2d = 63.3, the 3d = 67.9; the lowest the 1st in 1867 = 51.1; the highest the 3d in 1881 = 77. The highest mean temperature of a single day of March was in 1875 on the 30th = 65.6; of April in 1872 on the 29th = 77; of May in 1860 on the 24th = 85.1; the lowest of March in 1867 on the 13th = 4.7; of April in 1857 on the 6th = 13.7; of May in 1875 on the 1st = 39.5. The highest stand of the thermometer was observed in March, 1860, on the 30th = 79; in April 1856 on the 26th = 88.5; in May 1860 on the 24th = 98.5; the lowest in March 1867 on the 14th = —6; in April 1857 on the 15th = 18; in May 1867 on the 8th = 30.

There are in average 18 frost days in March, 5 in April, and in May 5 were observed in 30 years. The most frost days had the March in 1859 = 29, and April in 1857 = 18. There was no frost day observed in April 1878; only 13 per cent. of the frost days of April occurred after the 17th, at which date for the last time a mean temperature below freezing point was observed.

SUMMER.

The mean temperature of the three summer months is 75.5. The coolest summer was in 1866 and 1869 = 73; the warmest in 1874 = 79. The coolest June in 1869 = 69; the coolest July in 1865 = 71; the coolest August, 1866 = 70; the warmest June in

1873 = 79; the warmest July, 1868 = 82.7; the warmest August, 1881 = 80.5. The mean temperature of the decades was, of June, 1st decade = 70, 2d = 73, 3d = 77; of July, 1st = 77.9, 2d = 78.3, 3d = 77.2: of August, 1st = 77, 2d = 75.6, 3d = 73.3. The coolest decade of June was the 1st of 1863 = 63, of July the 2d in 1865 = 65.3, of August the 3d in 1863 = 65.3; the warmest in June the 3d in 1858 = 85, in July the 2d in 1878 = 89.8, in August the 1st in 1861 = 86.7.

Of the single observations was the highest for June on the 24th, in 1856 = 100; for July on the 15th, 1859, on the 4th, 1874, and on the 30th, 1885 = 104; for August on the 31st in 1873 = 105; the lowest for June on the 4th, 1859 = 35; for July on the 2d in 1861 and the 16th in 1863 = 50; for August on the 29th in 1863 = 41.

FALL.

The mean temperature of the three fall months is 53.3. The coolest fall was in 1880 = 48.9; the warmest in 1884 = 58.1; the coolest September was in 1866 = 60.5; the warmest in 1865 = 73.1; the coolest October in 1869 = 48.2; the warmest in 1879 = 62.7; the coolest November in 1880 = 30.3; the warmest in 1867 = 44.4.

[TO BE CONTINUED.]

CORRESPONDENCE.

A FOG-BOW AND "GLORY."

To the Editors.—I have recently seen a reference to the fog-bow and "glory" observed occasionally on the Brocken, and it brings to mind an observation of my own of the same phenomena, which, although made several years ago, may still prove of interest.

The observation was made on the steamer Strassburg, just off the Banks of Newfoundland, on Sept. 29, 1883.

The morning had been so foggy that the whistle was sounded frequently, but as the sun got higher the fog thinned and one could see to a considerable distance, when at 9h. 48m. (A. M.)

a fog arch was observed, the fog hanging low at the time. This arch was a band of light about 3° wide, with a greatest altitude of not more than 10° from the horizon, and the distance between the ends where they cut the horizon was about 30°. This band of light was lighter at the inner edge than the outer, but no distinct colors were visible. As the fog grew thinner a little color could be seen, and a little later (10h. ?) the whole circle was visible, most of it being seen against the water, and the nearest part of the circle of light appearing to be very close to the ship. I walked to the edge of the ship in order to observe the bow a little better, when my eye fell on ray shadow in the water, and I was astonished to see the shadow of my head encircled by a brilliant "glory" of light about four times the shadow of the head in diameter. I called the attention of the navigation officer to the phenomenon, and as he "had never seen it before in all of his experience" I concluded that it was rarely observed at sea. Each observer could see it around his own shadow only, and the shadows of others presented the usual appearance.

FRANK WALDO.

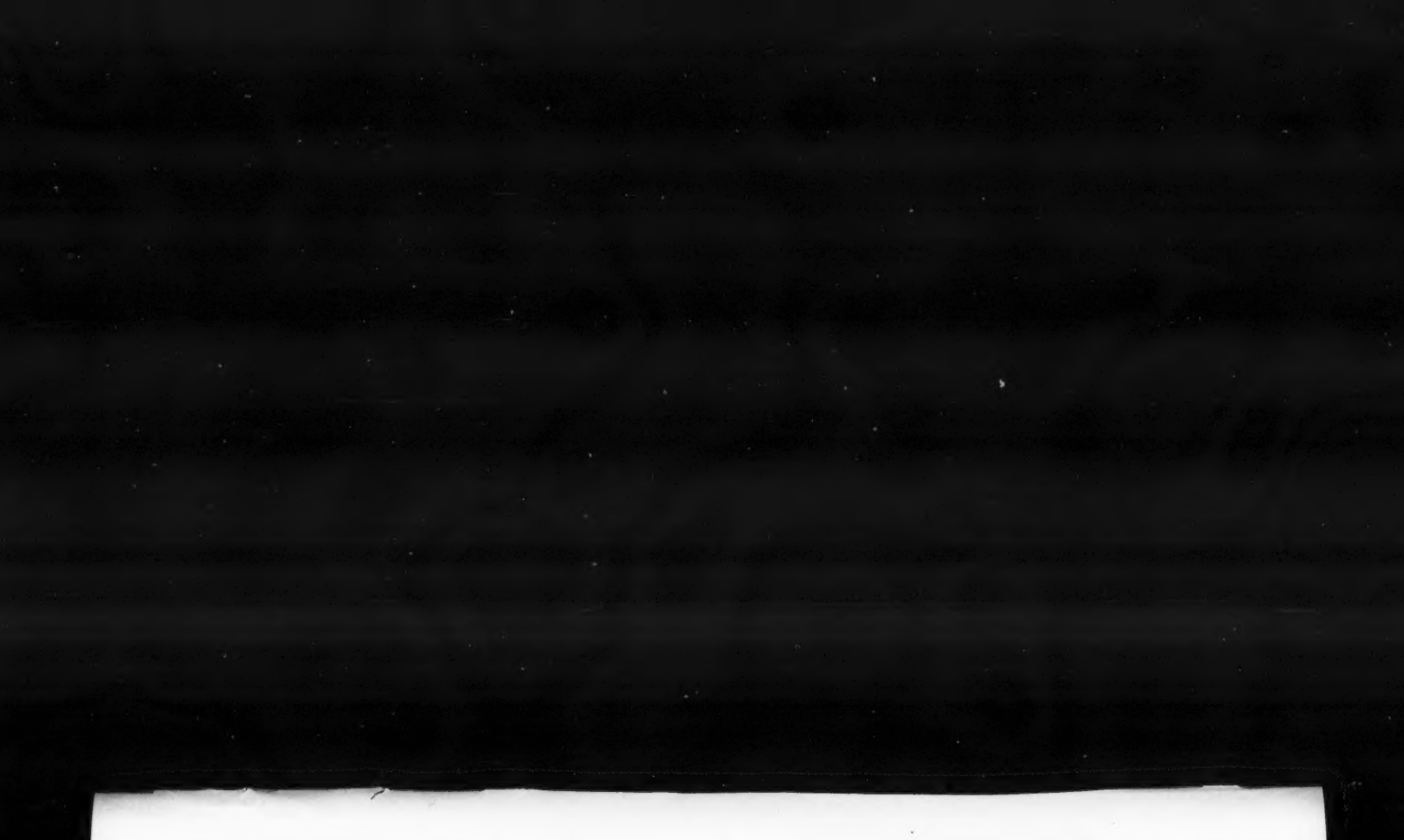
CINCINNATI, August 25, 1887.

THE BAROMETER IN TORNADOES.

To the Editors.—In the August number, page 171, it is stated: "We have not a single observation on land showing any fall (of bar.) on the approach of a tornado, but we have several showing an undoubted rise." I would like to have date and place of the rise in pressure referred to, as my information and experience are entirely to the contrary. I have not found it to occur in daily weather bulletins, for nearly all tornadoes of '83, '84 and '85. All my personal experience is to the contrary; tornadoes have occurred within 6, 25, 40 and 60 miles, invariably preceded and accompanied by low barometer. The Kansas City *Times*, May 14, 1883, stated a steady fall of the barometer for half an hour preceding the tornado of May 13, 1883, at that place, and the lowest ever known.

J. F. LLEWELLYN.

MEXICO, MO., August 26, 1887.



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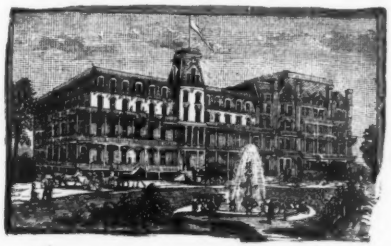

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